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THE UNIVERSITY OF ALBERTA

A CROSS-MODALITY MATCHING STUDY TO INVESTIGATE ASSOCIATIVE MECHANISMS

by

© MARTHA CLEE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled A CROSS-MODALITY MATCHING STUDY TO INVESTIGATE ASSOCIATIVE MECHANISMS submitted by MARTHA CLEE in partial fulfilment of the requirements for the degree of Master of Science.

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Date November 4, 1976

ABSTRACT

Sixteen subjects attempted to replicate the intensity of a criterion stimulus after one and two cross-modality matches. Matches involved visual or auditory criterion stimuli matched to kinaesthetic, visual and auditory output. It was found that within subjects, the number of matches made in each trial had no effect on the memory of the criterion stimulus.

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INTRODUCTION

It has been asserted (Pribram, 1971) that a comparison process is involved in associations between sensory modalities. Current sensory excitation is screened against some representative record of past experience.

Recently there have been detailed associational mechanisms suggested. Konorski (1967) proposed a system of directional connections between units of specific storage areas. Luria (1973) hypothesized the existence of higher associational areas formed by the overlapping of cortical ends of various analyzers. Evidence of specific dimensions for comparisons between specific modalities has been found by Auerbach and Sperling (1974), Connolly and Jones (1970) and is suggested by Signal Detection Theory (Coombs et al, 1970). A more extensive review of literature can be found in Appendix II.

Pribram (1971) suggests that association between modalities occurs through units of the primary projection areas in the brain that are sensitive to excitation in a modality different (cross-modality) than the major sensory mode served by that system. The following experiment uses this concept of multi-modality matching to compare the accuracy in matching over two and three different modalities, namely; visual, auditory, and kinaesthetic. A statement of the problem is found in Appendix I.

EXPERIMENTAL DESIGN

Two conditions were presented in a factorial design with two modalities. The modalities consisted of criterion stimuli presented in visual (V) and auditory (A) modes. Visual stimuli were intensities of light at 5.0, 8.75, 12.5, 16.25 and 20.0 Watts. Auditory stimuli were loudnesses of sound at 59.0, 65.8, 72.5, 74.3 and 75.8 dB.

The first condition consisted of a criterion stimulus presented for five seconds. The subject (S) was required to judge the intensity of the stimulus and to produce an extensor arm movement (K) of a length corresponding to that intensity. He was then asked to use his appropriate control knob to try to reproduce the intensity of the original criterion stimulus. Thus, the criterion was presented, S gave a kinaesthetic response (K) and then a response in the original modality. For example, a visual criterion was followed by a kinaesthetic response and then a visual response. This is shown as V1→K→V2, where 1 indicates a presented stimulus and 2 a response (K is always a response).

Condition Two used the same criterion stimuli, but one additional response was required before the K response and the attempt to reproduce the original. For example, a visual criterion was followed by an auditory response, a kinaesthetic response and then the final visual response. This is shown as V1→A2→K→V2. Table 1 shows the four combinations used.

Table 1

Experimental Design for the Cross-Modality Matches Given to all Subjects

	Modality	
	Visual	Auditory
Condition One	V1→K→V2	A1→K→A2
Condition Two	V1→A2→K→V2	A1→V2→K→A2

Ten trials in random order (five criterion levels given twice each) were given on each combination. The order of the combinations was varied between subjects, but Condition One always preceded Condition Two.

METHOD

Independent Variables

Visual intensity (V) and auditory loudness (A) were matched to the kinaesthetic sense of length of arm movement (K) using a cross-modality matching (CMM) test. See Appendix III for specific definitions of terms, stimulus variables and response variables.

Subjects

Sixteen summer session students and secretaries were paid $2.00 each to be subjects (S) in the experiment.

Apparatus

The apparatus consisted of devices for measuring K, V and A. Figures 1 and 2 illustrate the apparatus used. A wooden bar calibrated in centimetres was equipped with two metal clamps as stops and a freely moveable cursor with a handle. This was used to measure the length of the S's extensor arm movements (K) directly in centimetres. S could reach the cursor easily with his right hand, but could not see it as his right arm and hand were covered by a cloth fastened around his neck. The experimenter (E) had a clear, illuminated view of the wooden bar.

The device for measuring V was a 25 Watt light bulb connected to a variable transformer which varied the power to the light bulb over a range of 0 to 25 Watts. S viewed the light bulb through a small hole at his eye level. The variable transformer was equipped with a dial which E could read and manipulate.

FIGURE 1

APPARATUS: SUBJECT'S SIDE

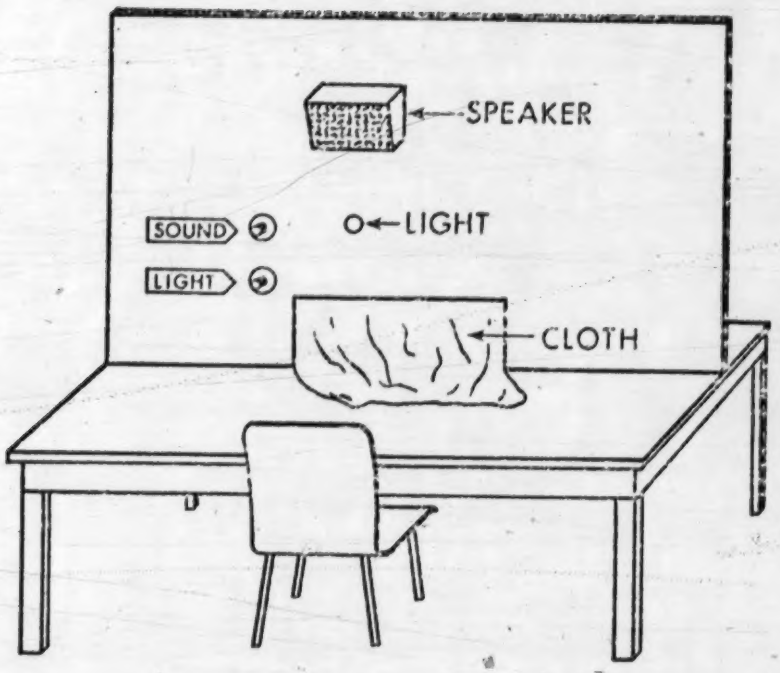
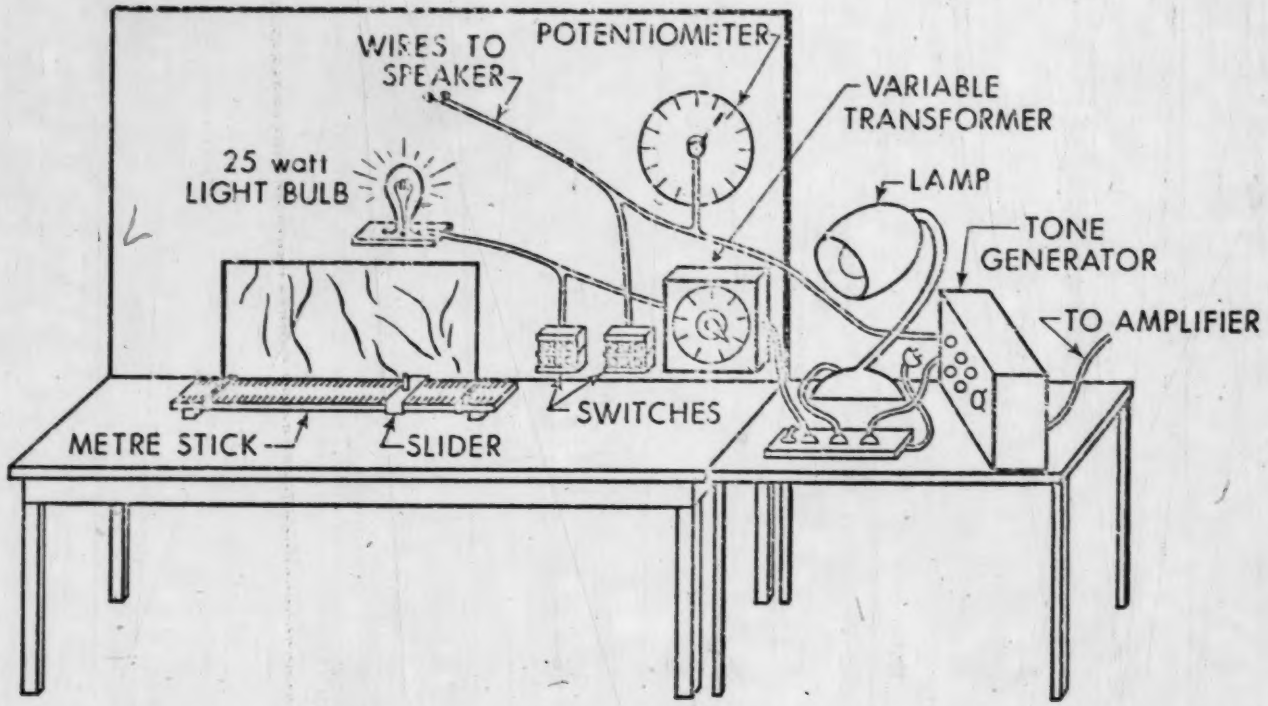


FIGURE 1

APPARATUS: OPERATOR'S SIDE



With his left hand, S could reach a knob directly connected to the dial of the variable transformer with which he could vary the intensity of the light.

A potentiometer calibrated in decibels was connected in series with a speaker, tone generator and amplifier to regulate the loudness of a 1000 Hz tone. The potentiometer, similar to the variable transformer, had a dial which could be controlled by S or E to vary the loudness of the tone (A). E controlled circuit switches for both the V and A devices and had manual access to the K measurement. See Appendix IV for actual experimental procedure and instructions to subjects.

RESULTS

Absolute (AE) and algebraic error (CE) scores were computed for each trial by comparing the presented intensities with final responses in the same modality. (See Appendix V.) A four-way analysis of variance was performed on AE scores. There was no significant difference found between conditions. The similarity between conditions is illustrated by the graphs in Figures 3 and 4. This suggests that the criterion level of sensitivity stays constant with multi-modality matching. Modality differences were not comparable.

Variable error (VE) scores (standard deviation from algebraic mean) gave similar results for the two conditions. This analysis showed significant subject differences, $F(15,35) = 18.7$, $p < 0.01$. This supports the work of Rule and Markley (1971) who found subject differences and concluded that they were due to idiosyncratic use of the dependent variables. No interactions were found significant except the subject by repetition interaction. This indicates that over trials, subjects became more precise.

FIGURE 3

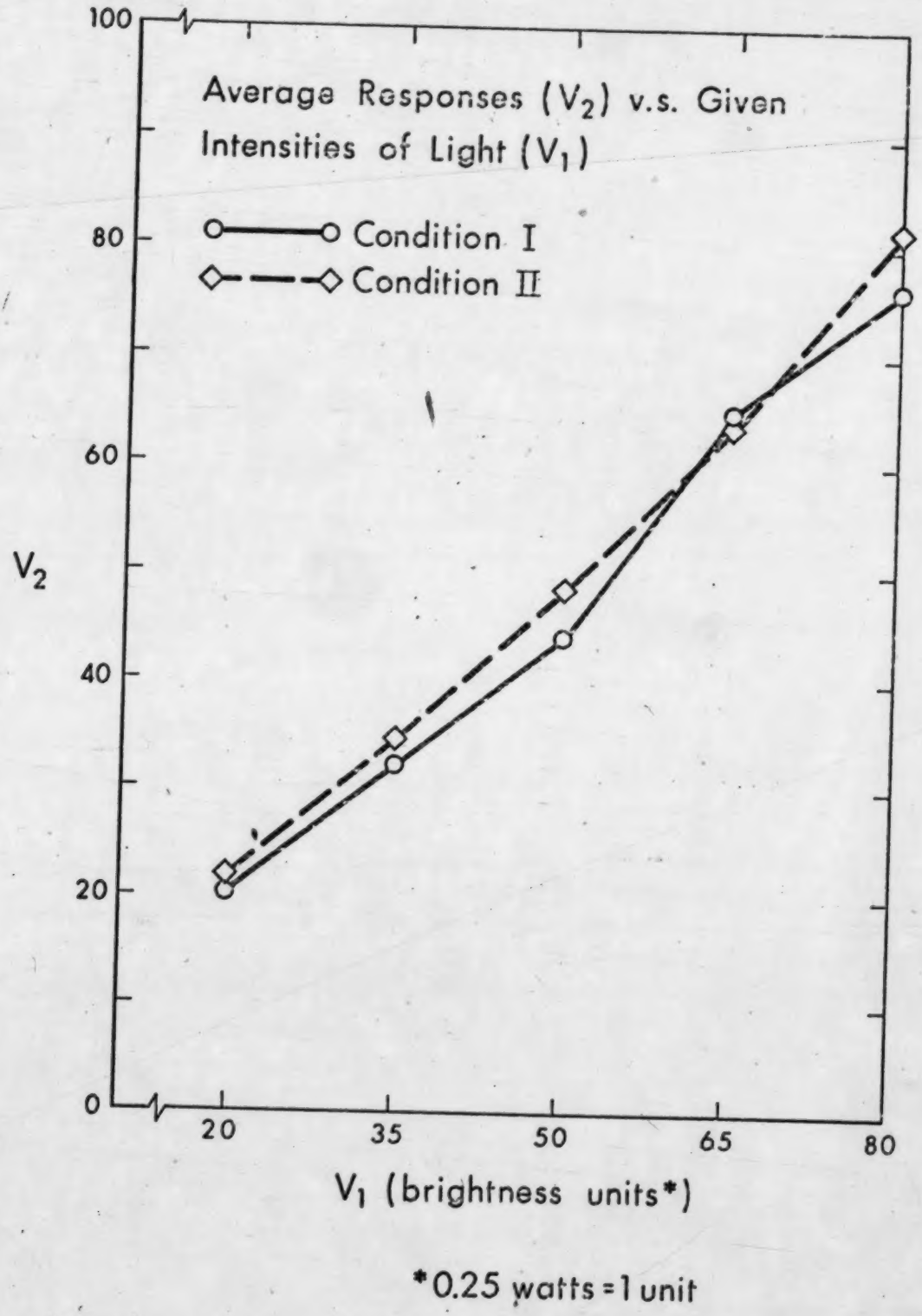
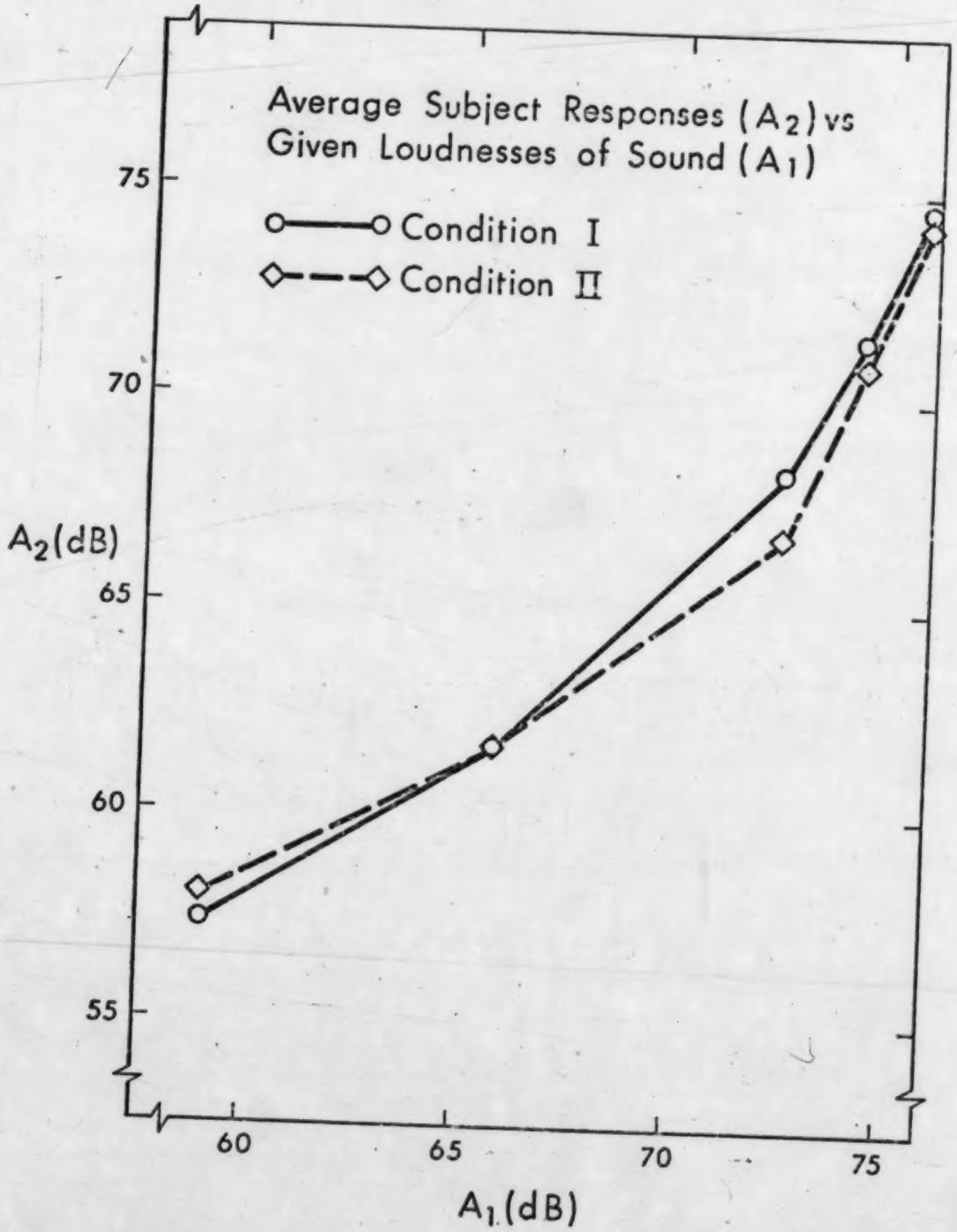

Average Responses (V_2) v.s. Given Intensities of Light (V_1)
Condition I
Condition II
100
80
60
40
20
0
V_2
20
35
50
65
80
V_1 (brightness units*)
*0.25 watts = 1 unit

FIGURE 4


Average Subject Responses (A_2) vs
Given Loudnesses of Sound (A_1)
Condition I
Condition II
75
70
65
60
55
A_2(dB)
60
65
70
75
A_1(dB)

DISCUSSION

Results reported here have indicated that a beta level (criterion level of sensitivity) is set up and stays constant with multi-modality matching. If the match was made on the basis of the preceding feedback, the regression noted by Stevens (1969) would alter the beta level for the following match. The consistency of the matching in this experiment suggests that a central beta level is established common to all modalities, denying the connectionist approach to association.

Pribram's (1971) holographic model for memory storage and association is compatible with these results. His theory would have the beta level stored in units of the primary projection cortex that are sensitive to inter-modal associations. The work of Auerbach and Sperling (1974), Connolly and Jones (1970) and Signal Detection Theory (Coombs et al, 1970) also propose a central decision axis or storage system of some kind. No specific structures are proposed by these authors.

Luria (1973) suggests a central mechanism at a higher level rather than within primary systems. This experiment makes no distinction as to level of association, but Luria's model would involve complex connections that have not been substantiated.

The efficiency of the human analyzer supports the extension of the associational information reported here for visual auditory and kinaesthetic modes to include all sensory modalities in a model of association using a central decision axis.

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APPENDIX I

THE PROBLEM

Stevens (1969) has noted that a regression effect or centering tendency occurs in CMM experiments. The subject tends to shorten the range of the stimulus variable he controls. When multiple matches are made, this regression error may be compounded if the match is made on the basis of feedback (input) from the immediately preceding match. This would imply a connectionist association mechanism. If, however, the match is made against a central sensitivity level common to all modalities, the regression error should be minimal and not compounding.

The problem may be clearly stated as the following questions: Does the criterion level of sensitivity (β level) stay constant with multi-modality matching? Does the error due to regression in the manipulated modality alter the β level for further matches? What are the associational implications of the results?

APPENDIX II

REVIEW OF LITERATURE

Sensory Perception

The properties of the sensory modalities and their interactions are important for efficient human performance. Hartshorne (1934) stressed the idea of separation between the modes of sensation. This idea has been developed into a generally accepted concept of division of the brain into modality specific areas. Information specific to each modality is thought to be stored in a corresponding area of the brain. Visual information, for example, is centered in the occipital lobe of the cerebrum, while audition is located in the temporal lobe. Motor areas are not so highly localized, although they are centered in the posterior section of the frontal lobe with the visual motor area in the parietal lobe (Grossman, 1973).

Each modality has peripherally located receptors that are stimulated by incoming information. This stimulation is coded into an array of nerve impulses which reach the synaptic networks of the primary projection area. This pattern of impulses is coded into the brain's continuous pattern of slow potentials to produce an internal representation or coded image of the stimulus (Pribram, 1971). The patterns of encoded stimuli are decoded into patterns of nerve impulses, transmitting information to the appropriate storage centres (association cortex).

Posner's (1969) concept of the coded image is that of a spatial array that can be searched. Pribram (1971) takes this idea further.

He suggests that since the movement of the slow potentials is somewhat describable as wave forms, the coded images may be similar to holographic images. Holograms are described by the same convolution integrals used for analysis of wave interference patterns. Essentially, the neural equivalent is spatial interactions among phase relationships of neighbouring junctional patterns. A physical process based on interference effects (resulting from the lateral inhibition occurring in neural events) displays many of the attributes of the neural process of perception. This holographic type of transformation, combined with feature filters, describes a mechanism of creating a neural image of stimuli. These images can be decoded for storage and reconstructed at will. Further holographic features are that many different patterns can be simultaneously stored and individually retrieved from the same storage surface, and that a whole, three dimensional image may be reconstructed from any part of the storage area (Pribram, 1971, Ch. 8). Such a process readily describes a mechanism of image formation and the capacities of recognition memory.

Konorski's (1967) theory of gnostic units as units of recognition is based on the concept of neural activity as all or none firing of individual neurons. He stresses the importance of synaptic modification through repeated stimulation to establish learned pathways to recognition units as well as directional associative links between units. This idea is compatible with the slow potentials and holographic coding hypothesis. The patterns of stimulation resulting from decoded images require synaptic transmission to points of storage that can be stimulated to recode the stored interference patterns.

Pribram (1971) suggests that although research on spacial interactions in junctional patterns has centered on the visual system, the auditory and kinaesthetic systems may provide similar models.

Posner (1973), names three qualitatively different codes with which this study in concerned; iconic codes to represent visual images, echoic codes for auditory images, and enactive codes to represent motor programs. Differences between these codes appear when attentional factors are considered. All three decay rapidly with time, although iconic and echoic retention can be aided by the availability of attention (rehearsal). However, attentional factors appear to have a much reduced effect on the storage and performance of enactive codes.

Association

In order for the organism to act as a functional unit, there must be extensive associations established between the sensory systems. Aristotle (cited in Takatura, 1971), in the fourth century B.C., defined a first sense, "sensus communis", as a central organ common to all special sensations. Special sensations were termed as those which act in terms of special organs such as the eye, ear, or nose. The sensus communis was assigned responsibility for the comparison, descrimination, and the unity of special sensations.

Co-ordinated, unified activity of the brain appears to require extensive associational connections between the sensory modalities. Codes of different types are assumed to be of different formats. Consequently, if matching is to occur between modalities, internal transformation of information from the storage code to the appropriate code for

comparison must occur. Swanson et al (1972) termed that operation "recoding."

Although the actual mechanisms of association are not understood, there is most likely a comparison process involved. Pribram (1971) asserts that:

> At any moment, current sensory excitation is screened by some representative record of prior experience; this comparison - the match between current excitation and representative record - guides attention and action. (p. 49)

Recently there have been detailed associational mechanisms suggested. Konorski (1967) proposed a system of directional connections between units of specific storage areas. These connections are neural pathways that could be established by synaptic modifications as experience and importance to the organism dictate.

An alternative to this connectionist approach hypothesizes the existence of a higher associational area which operates by convergence of information from the modality specific storage areas. Luria (1973) proposes a specifically human structure of overlapping of the cortical ends of various analyzers to form areas concerned with the integration of excitation arriving from these different systems.

Auerbach and Sperling (1974) present evidence for the existence of a single direction dimension common to auditory and visual direction for purposes of comparison. Connolly and Jones (1970) propose the existence of a long-term integrated storage system which contains some internal representation of the relationship between visual and kinaesthetic information to facilitate translation between these modalities. Multi-dimensional stimulus inputs are presumed to be

mapped into a one dimensional decision axis in Signal Detection Theory (Coobs et al, 1970). These contributions may imply a higher associative area or merely affirm commonalities between modalities at primary levels.

Pribram (1971) doubts the existence of associational connections between areas, or that there is a solely human associational structure. He suggests that association occurs through units of the primary projection areas that are sensitive to excitation in a modality different than the major sensory mode served by that system. He notes that lesions in the primary projection cortex disturb inter-modal associations more than lesions in the so-called association cortex. One of the attributes of the holographic hypothesis, a mechanism of the primary projection areas, is facility in associative recall. Many connections and fibre tracts exist between areas of the brain and between the left and right hemispheres. These connections serve to distribute coded representations throughout the brain and are suggested to have inhibitory rather than associational functions (Pribram, 1971).

The Measurement of Sensation

Perception of a stimulus involves transformations of the original energy received, so that what exists may not be the same as what is perceived. The problem then, is how to accurately measure sensation.

Fechner (1860) first measured sensation in terms of successive increments of just noticeable differences (jnd's). He assumed all jnds to be subjectively equal, and to represent constant differences in sensation. His work resulted in the relation

$$\psi = k \cdot \log \phi$$

where ψ is the magnitude of psychological sensation, ϕ is the stimulus magnitude and k is a constant dependent on units of ϕ. Stevens' psychophysical law is based on the concept of a jnd as a value which is a constant proportion of the original stimulus, so that jnds are constant ratios of sensation (Miller, 1959). However, Krantz (1972) would argue that sensations are internal mediators, not numbers, so the term "ratio" is undefined in this case. Stein (1975) disputes the use of the term "law" in relation to the psychophysical law. The only scientifically lawful relation between stimulus and sensation is the hyperbolic relation which exists between receptor potential and conductance change after encoding (Stein, 1975).

The much debated psychophysical law states that:

> Every sensory continuum exhibits the same invariance: equal stimulus ratios produce equal sensation ratios. (Stevens, 1966, p. 5)

Stevens has used this law with methods of magnitude estimation (numbers are assigned in proportion to sensory magnitudes) to find a relation between sensation and stimulus:

> The sensation magnitude ψ grows as a power function of the stimulus magnitude ϕ. In terms of a formula,
>
> $$\psi = k\phi^n.$$ (Stevens, 1959, p. 115)

The exponent, n, of the power function is roughly a constant expression of the rate of growth of sensation magnitude, specific to each sensory continuum.

There are some problems associated with this function. The size of the exponent may vary with stimulus range used, in that a smaller range results in a larger exponent. Engeland and Dawson (1974) found

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persisting individual differences between subjects. Procedural differences can alter the exponent, methods of magnitude production giving a larger exponent than magnitude estimation (Marks, 1974). Magnitude estimation requires assigning numbers to given stimulus intensities, while in magnitude production, the experimenter gives numbers to be matched by adjusting the stimulus intensity.

Krantz (1972) prefers the method of relation theory to these magnitude estimations. In relation theory, any stimulus is judged in a context of previous and concurrently present stimuli, and judgments are mediated by perceived relations pertaining to pairs of stimuli. He points out that this latter method more closely approaches what he actually does when comparing two stimuli. This relation theory is the basis for cross-modality matching.

Cross-Modality Matching

Cross-modality matching (CMM) experiments require that subjects match the magnitude of sensations produced by stimuli of one modality to sensations produced by stimuli of another (Auerbach, 1973). CMMs are based on the discriminability of stimuli rather than on the magnitude of sensations they produce, so the questionable validity of measuring magnitude of sensations is circumvented.

Signal Detection Theory has been established with a beta (β) value as a level of sensitivity common to all stimulus inputs. Signal detection operates on the basis of a known likelihood ratio which expresses the probability distribution of the occurrence of the signal. A beta level is determined using factors of prior odds and values of responses

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as a cut-off level or threshold for comparison with the likelihood ratio (Coombs et al, 1970). In the present study, the probability of occurrence is always one and the value of a correct response is always of prime importance. As well, there is no problem distinguishing signal from noise, as the given signal is always well above threshold. A beta value established in this CMM case would provide a decision axis for discrimination of an equal sensation in another modality. Thus, this beta value shall be considered the basis for comparison in cross-modality matches.

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APPENDIX III

Definitions of Terms

CMM: Cross-modality matching; this indicates the matching of received stimulus magnitude of a sensory continuum in one modality with output of sensory magnitude on a second sensory continuum in a second modality.

Beta (β): a level of sensitivity determined by perception of an input stimulus; a decision axis (same or different) for matching of further variables.

S: subject

E: experimenter

Stimulus Variables (Independent Variables)

A1: auditory modality; input given as loudness of tone.

V1: visual modality; input given as brightness of light.

Response Variables (Dependent Variables)

K: kinaesthetic modality; operationally measured as length of arm movement (extensor) originated by S to match V1 or A1.

V2: visual modality; operationally measured as the brightness of a light, manipulated by S to match V1 or A1.

A2: auditory modality; operationally measured as loudness of sound, manipulated by S to match V1 or A1.

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APPENDIX IV

EXPERIMENTAL PROCEDURE

Each subject was placed carefully in a chair, so that he was lined up with the light source and the speaker and was within reach of the control knobs and K cursor. He was briefly instructed on the operation of the control knobs and was allowed to see and try out the cursor. Then a black cloth was fastened around his neck leaving his left hand free to reach the control knobs and his right arm and hand hidden to manipulate the cursor unseen by himself. The lights were then turned off and instructions given as S became dark adapted.

The instructions to subjects were as follows:

> "There are three factors which you can control: brightness of light, loudness of tone and length of arm movement. Movement length is just the natural extension of the arm. Try the range of brightness of light. (S tried it). Try the range of loudness of tone. (S tried it). I will give you an intensity of light or a loudness of sound for five seconds. Concentrate on it. After the signal finishes, you will be asked to respond on the basis of that signal. There are four response orders. Before the experiment begins, we will have a few practise trials on each order.

Here were given two practise trials on each of the first two configurations to be given (Condition 1) and one on each of the last two (Condition 2). Practises were given in the same order as the actual testing. Each subject received the same intensities for practise (light at 40 and 70 units, sound at 60.4 and 73.5 dB). Any questions as to procedure were answered and subjects were requested to respond as accurately as possible on all attempts.

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APPENDIX V

Table 2

Mean Error Scores

for Modalities and Conditions

	AE	CE	VE	AV *
Visual	6.44	1.01	5.66	7.93
Auditory	3.41	2.95	2.50	2.83
Condition 1	4.88	2.42	4.19	5.34
Condition 2	4.98	1.54	3.97	5.42

*AE = Absolute error

CE = Constant (Algaebraic error)

VE = Variable error

AV = Average variation

APPENDIX VI

IMPLICATIONS FOR PHYSICAL EDUCATION

Every physical educator makes use of the cross-modality matching phenomenon when teaching motor skills. A verbal explanation accompanied by a demonstration gives the student visual and auditory input to match with kinaesthetic output as he tries to perform the movement. Whether this match takes place against a central stored image or peripherally between modalities will affect the learning and teaching processes.

This thesis supports the theory that a central image is formed for comparison between all sensory modalities. This allows the teacher to draw on any appropriate comparison that would suggest the desired movement and help create an accurate image. For instance, a dancer may find a quality of movement suggested by a colour. Similarly, the colour red may suggest power to a volleyball player attempting a spike. There are few limits to the associations possible, and the inventive teacher will use cross-modality matching where needed to strengthen or correct a student's image of the movement (motor programme).

At times the student will have an incorrect image that must be altered or replaced. These bad habits are usually well learned by the kinaesthetic system, and the correction process can be long and arduous.

Awareness of the correct image is essential as is the student's awareness of how his own performance differs from that image. Visual feedback using mirrors or, better yet, videotapes will assist the student

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in feeling the image of his movement. Once the student is aware of how he is moving by using as much sensory input as possible to feel the movement, learning will be facilitated.

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APPENDIX VII

RAW DATA

Data is presented as written down at the time of experiment. For analysis, some transformations must be made. Kinaesthetic measurements must be subtracted from 79 to give the actual length of arm extension in centimetres (K). Visual measurements (V1, V2) were recorded as units on the dial of the variable transformer, where 1 unit = 0.25 Watts. Auditory (A1, A2) measurements were recorded as degrees of a circle describing the position of the pointer. The formula to convert this position to decibels is as follows:

$$y = 0.03801\ x + 0.00013\ x^2 + 54.36163$$

where x is the reading in degrees (°) and y is the equivalent in dB.

SUBJECT 1

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	65	68.4	65	290	45.3	272	65	139	64.8	47	255	54	59.8	101
2	50	70.9	47	185	62.9	198	80	178.5	54	81	185	56	59.4	168
3	80	56	88.5	255	54.9	246	20	62.5	64.9	29	255	67.5	54.6	219
4	65	61.7	72	185	61.4	233	35	53	58.4	42	185	56	60.9	163.5
5	50	66.9	48.5	255	62.4	237.5	50	171	56.7	66	290	88	44.4	250
6	20	72.3	23.5	272	52.3	251	80	195	49.9	83	272	69	55.5	262
7	35	67.6	35.5	272	50.65	269	35	105	61.6	33	93	48	62.8	75
8	20	70.2	21	290	44.4	269	65	130	54.3	68	272	75	54.2	271
9	80	57.1	82	93	68.1	56	50	130	57.2	63	93	55	65.1	111.5
10	35	62.2	42.5	93	70.7	55	20	52	66.6	25	290	91	41.8	276

SUBJECT 2

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	20	75.1	20	93	75.6	17	80	187.5	60	70	185	20	74.9	7
2	50	68	46	185	69.2	60	80	254	58	75	290	52	60.2	275
3	35	76.8	23.5	290	42.7	276	20	0	76.4	17	93	20	76.2	0
4	65	63.1	60	290	39.7	284	20	14	74.4	20	272	54	60.1	254
5	20	76.3	17	255	64.4	216	65	272	54.4	74	272	68	59.3	266
6	50	63.2	45	255	55.6	212	50	120	67.4	54	255	45	64	150
7	80	51.8	81	93	74.9	21	65	127	66.1	53.5	93	20	75.6	0
8	35	73.2	31	272	53.8	269	35	6	73.3	30.5	290	75	53.7	272
9	80	52.9	89	185	72.5	88	35	49	71	28	255	71	56.8	190
10	65	65.9	67	272	52	248	50	142	63.1	50	185	45	66.7	22

SUBJECT 3

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	65	47.7	64	185	61.2	86	20	39	73.9	19	255	33.5	60.8	100
2	80	58.3	41	93	68.1	20	35	132.5	57.3	33	290	99	31.4	278
3	50	64.1	26	272	44.8	214	65	126	49.5	44	93	18.5	75.5	16
4	20	77.3	13	255	48.5	226	80	187.5	48.1	60	290	98	35.2	276
5	50	55.1	35	93	69.3	21	50	118	63	39	255	48	57.2	66
6	35	66.8	31	290	33.4	227.5	20	25	72.25	20	272	52	48.8	168
7	80	62.4	84	272	59.7	179	65	199	37.1	64	272	60	37.7	165
8	35	70.2	26	290	43.2	276	35	83.5	61.1	31	93	34	70.6	23
9	20	75.1	18	185	73.2	53	50	133	50.2	35	185	41	60.7	112.5
10	65	54	47.5	255	62.3	108	80	264	31.4	100	185	43.5	58.4	84

SUBJECT 4

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	50	65.1	36	272	57.8	254	20	40	72.8	21	93	50	66.4	131
2	65	57.3	58.5	255	63.2	191	65	229	59.3	60	225	59	58.8	198
3	80	54.3	67.5	255	53.8	255	35	116	68.6	34	185	50	63.2	167
4	35	69.1	31.5	290	37.5	280	80	270	49.4	86	290	93	46.3	227.5
5	35	69.3	36	290	41.5	277.5	65	259	54.8	55	255	62	61.1	196.5
6	20	75.2	21	272	54.3	267	80	283.4	41.6	96	272	71	54.7	261
7	65	56.4	62	93	69	131	35	104	63.9	41	185	53	64.9	215
8	50	62.1	44	185	69.4	131.5	50	149	62.3	45	272	67	58.1	266
9	20	74.8	22	93	66.4	103	20	94	69.9	27	290	95	45.7	277
10	80	49.8	74	185	66.3	82.5	50	226	58.9	53	93	60	61.1	190

SUBJECT 5

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	35	68.6	30	272	58.2	267.5	65	249	57.8	57	93	31.5	63.7	162
2	20	75.2	20	255	63.1	243.5	35	184	68	29	185	41	58.4	216
3	20	70.4	19	285	54	278	20	32	73.6	20	255	49.5	58.8	237
4	65	59.2	50	185	68.2	191.5	50	203	60	39	285	70	49.3	287
5	80	51.9	61	285	47.7	284	35	78	67.9	26	93	36	64.5	179
6	80	46.9	90	272	62.5	270	80	277	47.1	75	255	51	60.5	257.5
7	35	68.8	21	255	67.8	195	50	188	61.8	44	272	46	59.5	255
8	65	59.3	54	185	65.4	225	65	264.5	56.1	69	280	69.5	49.1	290
9	50	64.2	40	93	70.4	97	80	265	52.4	72	272	44	61.9	271.5
10	50	65.4	39	93	70.3	156	20	22	74.3	20	185	30	70.7	145

SUBJECT 6

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	35	71.9	33	255	71.9	132.5	80	235.5	60.8	67.5	272	25	70.6	164
2	65	51	68	93	73.3	58.5	50	226	67.6	59	285	48	64.1	265
3	80	52.3	335	185	69.9	75	20	75	72.6	24	185	29	71	146.5
4	20	76.45	19	93	73.2	48	65	175	70.4	45	93	18	75.6	26.5
5	50	67.2	40	255	69.4	190	35	90	73.5	32.5	272	28	67.5	198.5
6	20	76.6	17.5	185	70.8	113.5	20	82	74	21	255	38	70.9	131.5
7	65	60	63	285	63.1	270.5	80	250	62.2	81	285	52	67.1	270.5
8	35	72.7	35	272	64.4	247	35	121	69.3	34	255	30	72.1	172
9	50	66.75	44	285	55.9	285	65	190	65.3	61.5	93	14	77.2	0
10	80	55.1	82	272	68.5	167	50	150.5	69.5	39	185	25	74.8	38.5

SUBJECT 7

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	20	67.8	14.5	185	67.1	127	20	169	66.4	26	285	49	59.1	241
2	80	54.6	72.5	272	51.5	262	35	139	65.1	37.5	272	83	56.4	252
3	35	61.4	25	185	60.4	163.5	20	36	72.1	20	185	43	68.3	165
4	50	60.7	55.5	255	58.4	257	50	239.5	59.3	62.5	255	50	61.8	212.5
5	20	65.4	24.5	272	56.5	266	80	280.5	53.3	98	272	94	59.5	242
6	50	56.5	58	93	72.3	24	65	260	59.7	72	93	25.5	72.8	41
7	65	52.5	81	285	44.5	271.5	50	113	72.1	43	185	38	67.1	169
8	65	56	89.5	93	75.2	0	35	94	71.1	31	93	29	72.4	48
9	35	66.9	38	285	55.8	270.5	65	240.5	59	73	285	93	55.4	263.5
10	80	47.3	82	255	65.7	220	80	262	56	87.5	255	37	68.9	174

ORIGINALS MARKED

SUBJECT 8

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	50	43.7	34	185	53.4	210	80	200	47.8	59.5	185	40	55.3	109
2	20	53.8	16	93	56.7	107	80	222	47.9	73	285	89	39.8	267
3	65	35.3	89	255	47.1	258.5	50	166	53.5	42	185	68	54.7	154
4	35	62.1	37	93	63	134	50	196	53.6	45	272	86	42.8	260
5	80	44.7	74	285	36.3	275	65	216.5	48.2	66	93	46	55.5	136
6	80	46.9	84	185	56.9	206.5	35	153	51.7	50	255	73	43.7	243
7	35	61.8	38.5	272	40.3	262	65	207	45.8	67	255	87	43.9	233
8	20	65.5	23.5	285	31.1	276	35	200	51.1	47	272	93	36.2	278
9	65	50	47	272	41.3	261	20	114.5	57	30	93	64.5	55.3	105.5
10	50	54.7	39.5	255	50.5	238	20	112	61.6	17.5	285	86.5	33.4	276

ORIGINALS MARKED

SUBJECT 9

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	20	69.5	21	285	45.5	281	35	46	69.3	26	93	21	69.6	20
2	80	44.9	64	255	52	194	65	273	41	81	93	31.5	65.8	76
3	35	57.3	30	272	43.8	273.5	50	96	53.4	41	272	73	47.6	250
4	65	44.7	61	285	35.3	290	80	270	40.8	70	255	56	57.3	220
5	35	59	35	272	40.8	263	50	166	55.3	285	285	68	43.6	284
6	20	71.2	16	185	63.6	108.5	65	264	42.1	64	185	40	65.8	111
7	65	40.5	61	185	65	84.5	80	268	40.3	80	285	93	35.4	288
8	50	54	45.5	255	52.7	252	20	4	72.8	24	255	62	58	192.5
9	80	44	82	93	64.7	40	35	99	63.1	33	185	53	60	139
10	50	57.2	44.5	93	64.3	41	20	42	69.7	18	272	68	45.6	262

ORIGINALS MARKED

ORIGINALS MARKED

SUBJECT 10

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	80	47.3	67.5	272	54.7	193	50	108	68.5	30	285	79	33.7	271
2	50	50.5	43	93	61	56	80	260.5	36.4	83	285	93	31.5	279
3	20	77.6	20	93	63	46	65	244	39.8	68	272	82	33.5	276.5
4	20	78.7	16.5	255	49.6	198	35	137	68.7	29.5	272	72	37.1	248.5
5	35	68.6	28	185	61.8	90	50	106	61.4	38	185	66.5	46.6	150
6	80	38.9	68	272	38.3	228	65	236.5	44.7	68.5	185	68.5	45.5	141
7	50	56.5	33	185	50.2	165	20	51	69.3	22	255	68.5	42.9	208
8	35	51.7	29	285	41.7	238	20	25	76.5	16.5	93	35	67	89.5
9	65	43.4	58	255	49.3	173	35	69	62.4	29	93	36	64.7	73
10	65	43	71	285	31.8	290	80	261	35.5	82	255	77.5	38	243

ORIGINALS MARKED

SUBJECT 11

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	80	51.7	74	185	60.9	122	65	247	53.5	64.5	272	85	53.6	233
2	50	64.7	49	93	65.6	56	80	254	48.5	82	93	50	63.8	94
3	20	70	36	285	40.7	266	50	152	59.7	53	285	90	50.8	279
4	35	66.8	37	272	49.3	276.5	35	48	64.4	47.5	93	37.5	70.3	45
5	65	57.2	68	285	34.1	290	20	0	71.1	32.5	272	68	57.5	221
6	65	56.8	71	272	43	266	50	160	58.8	64	185	71	57.1	132
7	35	68.9	29	255	49.7	234.5	20	30	67.2	24	255	73	55.3	215
8	80	55.5	83	185	54.7	112	65	137	60.4	70	285	100	44.1	282
9	50	59.7	61.5	255	47.5	213	35	80	68.1	43	185	64	60.1	149
10	20	71	30	93	63	59	80	257	54.5	86	255	66	54.9	226

SUBJECT 12

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	80	43.6	74.5	93	71.9	44	65	220	43.5	66	255	73	49.2	248
2	35	63	30	185	70.8	76	35	113	66.7	26	93	45	64.4	85
3	50	64.4	47	255	61	163	35	130	68.8	36	255	78	49.3	261
4	65	60	61.5	285	38	271	20	110	67.3	23.5	285	100	30	290
5	20	73.1	18	272	40.3	258	65	258	48.4	71	185	38	70.4	94
6	65	49.9	71	185	70.4	105	50	111	54	55	285	94	30.1	290
7	20	74.9	18	255	51.6	252	80	224	48	73	185	51	63.8	197
8	50	61.9	37.5	285	38.6	265	80	262	33.4	89	272	81.5	38.1	267
9	80	42.9	88	93	70.8	52	20	81	74.7	17.5	272	88.5	36	267
10	35	66.3	30	272	31.5	271.5	50	202	63.5	42	93	32	68.6	90

SUBJECT 13

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	50	62.7	49	272	57.1	182	20	64	70.5	17.5	285	69	59.1	268
2	80	52.1	77	93	68.2	70.1	65	286	51.2	68	285	84.5	56.1	270
3	35	72.3	24.5	93	67.3	48	80	290	45	100	255	41	68.7	146.5
4	65	61.3	58	272	53.7	265	35	114	68.7	31	272	43	72.6	163
5	35	70.7	31	285	56.9	262	35	152	69.2	28	255	47	65	151
6	50	67.3	42	255	66.1	221	20	37	75	20	93	19.5	76.6	23
7	20	74.9	19	185	71.8	111	80	274	51.1	88	93	18.5	75.2	46
8	20	75.3	20.5	185	68.8	157	65	230	57.4	64	185	29	73.1	80
9	80	49.5	81.5	285	46.5	290	50	227	63.2	58	272	55	59	225
10	65	58.7	65	61.2	61.2	194	50	110	65.1	35	185	35	73.4	137.5

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ORIGINALS MARKED

SUBJECT 14

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	35	62.4	34.5	272	56.5	245	50	188.5	60.4	48	93	27.5	69.9	71
2	50	52.8	55.5	255	57.1	228	80	280	53.2	80	255	47	56.7	200
3	65	52.5	68	185	63.7	98	20	34	72.4	20.5	255	49	59.5	219
4	35	70.2	27.5	93	69.4	66	65	246	56.2	64	272	61	56.8	263
5	20	73.4	20	255	57	229	20	23	75	21	93	26	72.5	18.5
6	50	59	43.5	93	68.7	68	50	167	60.5	45.5	285	93	49.1	277
7	80	28.8	79	185	65.2	138	65	190	57.3	62	285	77	52	275
8	65	56.7	58	272	51.8	252	80	277.5	50.9	93	272	66	55.9	204
9	20	72.6	24	285	43.8	274	35	157	64.1	39	185	54	60.4	178
10	80	53.2	61	285	47.6	281	35	119	67.7	33	185	36	64.9	101

SUBJECT 15

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	65	51.7	57.5	255	49.4	133	50	57.6	57.6	46	272	62	51.3	165
2	50	49.9	46	285	43.2	278	35	35	63.5	24	93	39	63.9	0
3	35	57.5	40	272	47.6	204	80	247	42.3	100	272	78	43.3	223
4	35	60.3	34	285	34.1	275	20	39	61.2	24	285	72	44.4	273.5
5	50	52.7	49.5	93	64.1	117	50	128	49.6	51	185	35	64.4	59
6	20	68.8	22	93	60.9	60	35	72	55.4	40	285	75	38.5	264
7	80	36.4	88	272	43.8	230	65	140	43	70	93	65	55.8	157
8	65	54.9	64	185	58.8	117	20	23	63.5	19	255	57.5	55.6	136
9	80	49.3	84	255	49.8	146	65	85	55.6	62	185	49	63.4	68
10	20	65.1	19	185	55.8	86	80	236	39.4	78	255	46	53.2	140

ORIGINALS MARKED

ORIGINALS MARKED

SUBJECT 16

ORDER	1			2			3				4			
TRIAL	V_1	K	V_2	A_1	K	A_2	V_1	A_2	K	V_2	A_1	V_2	K	A_2
1	50	51.8	40.1	255	46.3	247.5	65	179	54.5	43	185	335	62	120
2	65	40.8	75	185	53.7	123	50	119	57.1	46.5	272	80	51.7	247
3	50	57.4	50	255	47.2	182.5	80	196.5	46.7	84	272	77	48.9	268
4	35	66.5	37.5	272	39.6	266	20	50	64.7	21	255	61	53.3	230
5	35	61.1	36	185	59.5	114	35	87	59.4	35	285	65	37.8	266
6	20	68.8	21.5	285	32	280	50	147	54.9	51	285	83.5	45.2	276
7	80	39.7	70.5	93	62.5	41	20	42	65.6	21	255	88	50.1	243
8	65	40.9	71.5	272	42.9	242	80	263	39.7	90	185	52.5	55.7	156
9	80	52.6	62	285	32.1	276	65	236	47.9	75	93	26	66.8	43.5
10	20	66.3	24	93	65.6	44	35	130	63.3	33	93	35.5	62	81.5